Late-stage diagenetic concretions in the lacustrine Murray Formation, Gale Crater, Mars

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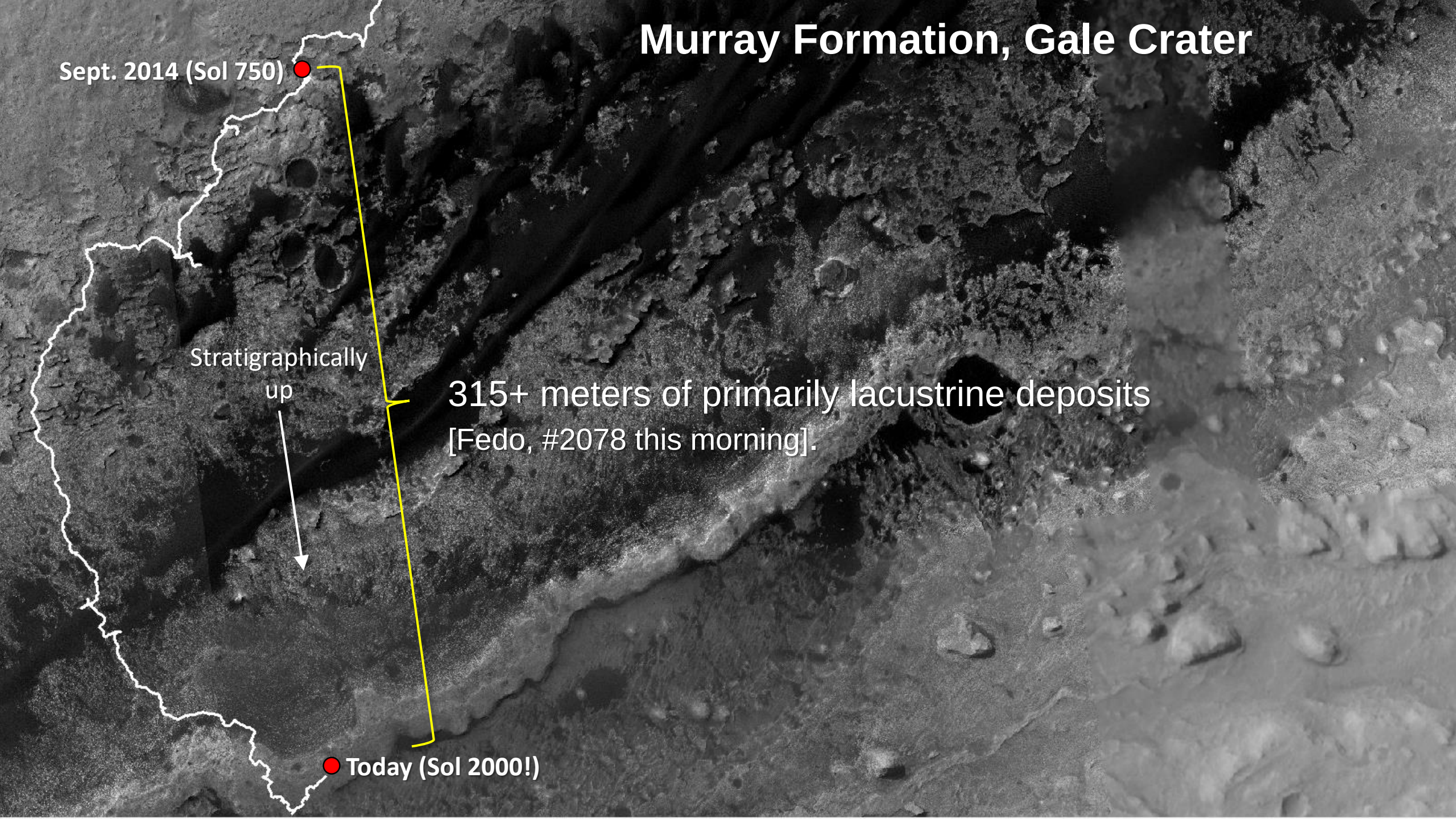
Nodule-rich outcrop Chuos, dubbed “Measle Rock” Sol 1256 (mcam05864)

Jet Propulsion Laboratory
California Institute of Technology


Murray Formation, Gale Crater
Sept. 2014 (Sol 750)
Stratigraphically up
315+ meters of primarily lacustrine deposits
[Fedo, #2078 this morning].
Today (Sol 2000!)

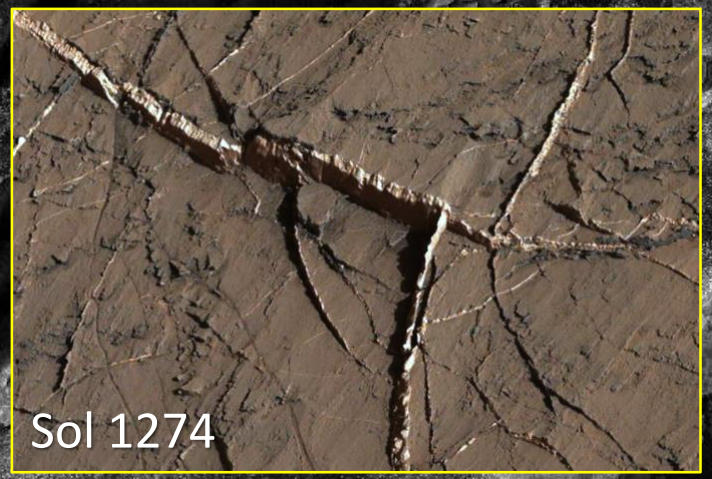
Murray Formation, Gale Crater

Sept. 2014 (Sol 750)

Today (Sol 2000!)

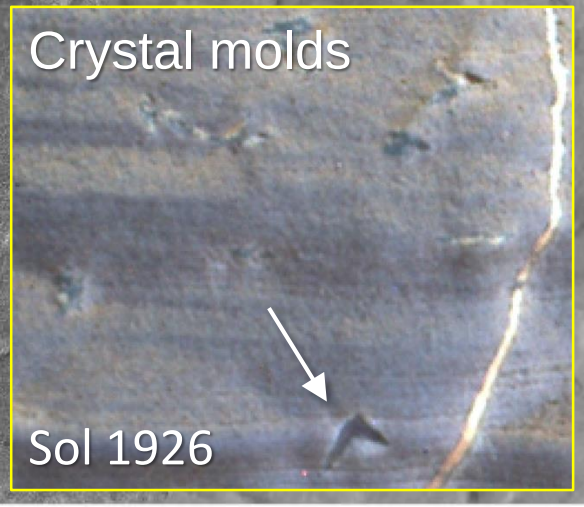
Variety of diagenetic features suggest aqueous activity after the initial deposition of sediment:

Veins...



...and Concretions throughout

Alteration halos



Murray Formation, Gale Crater

Sept. 2014 (Sol 750)

Today (Sol 2000!)

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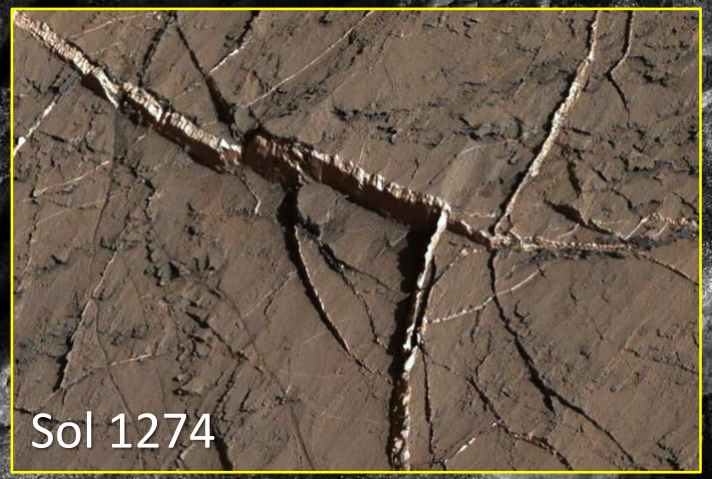
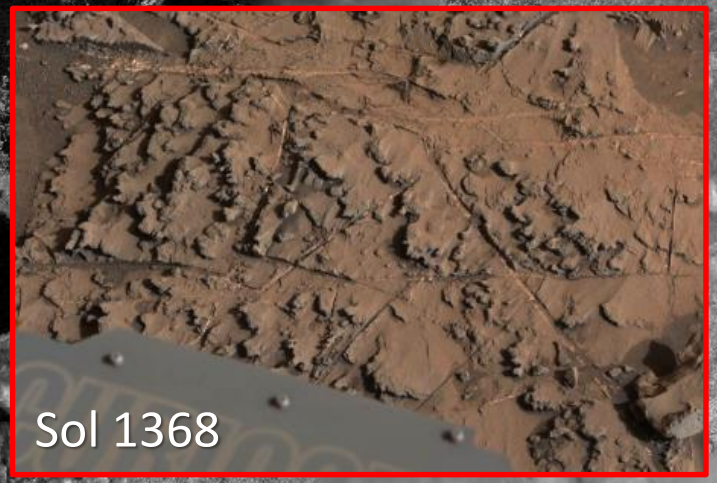
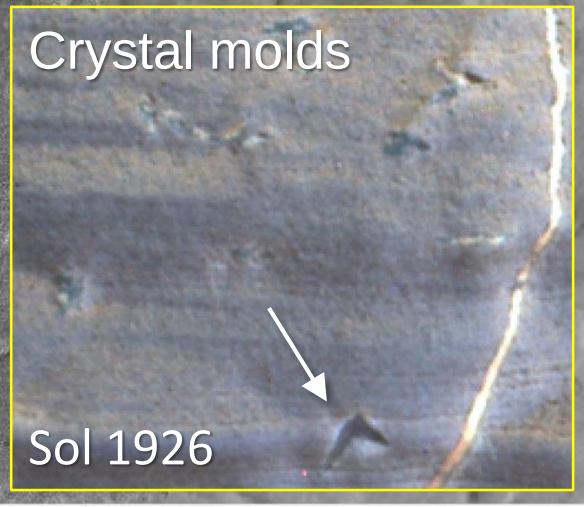


...and Concretions throughout



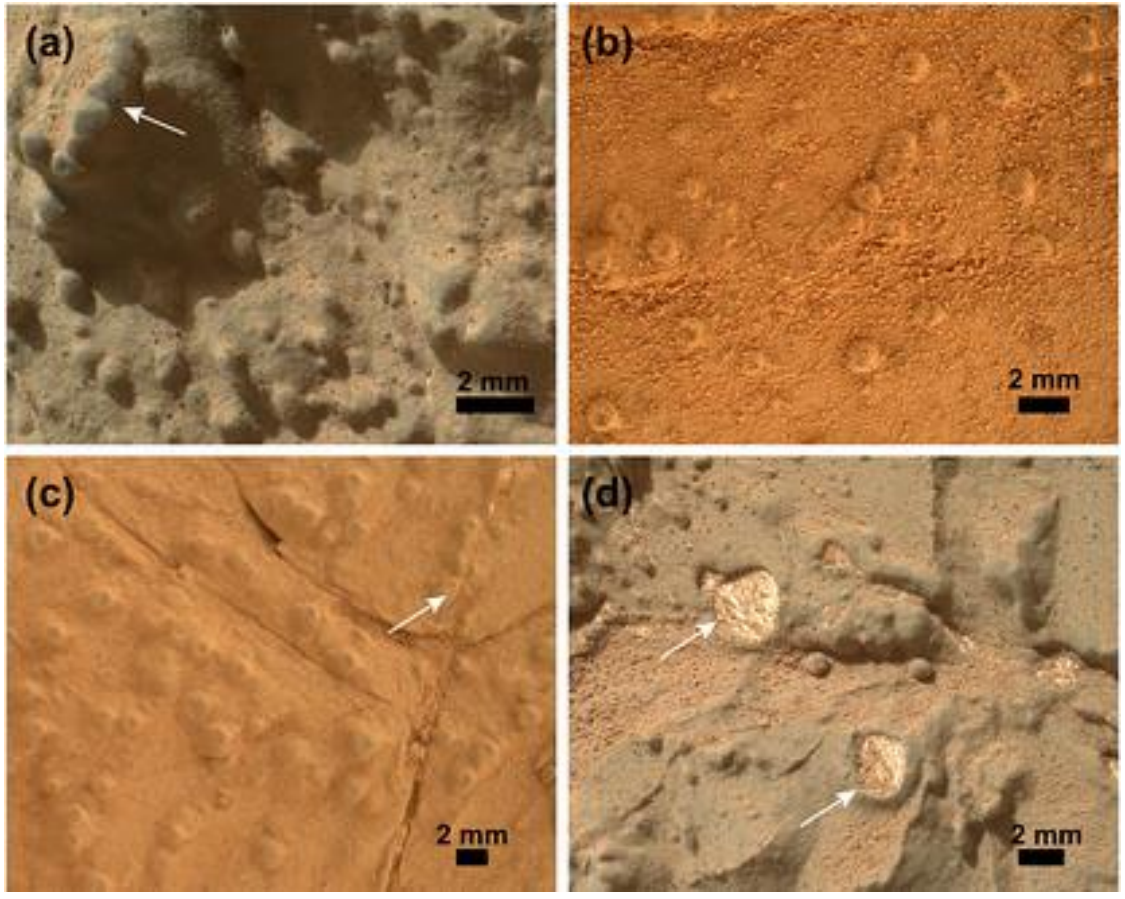
Alteration halos



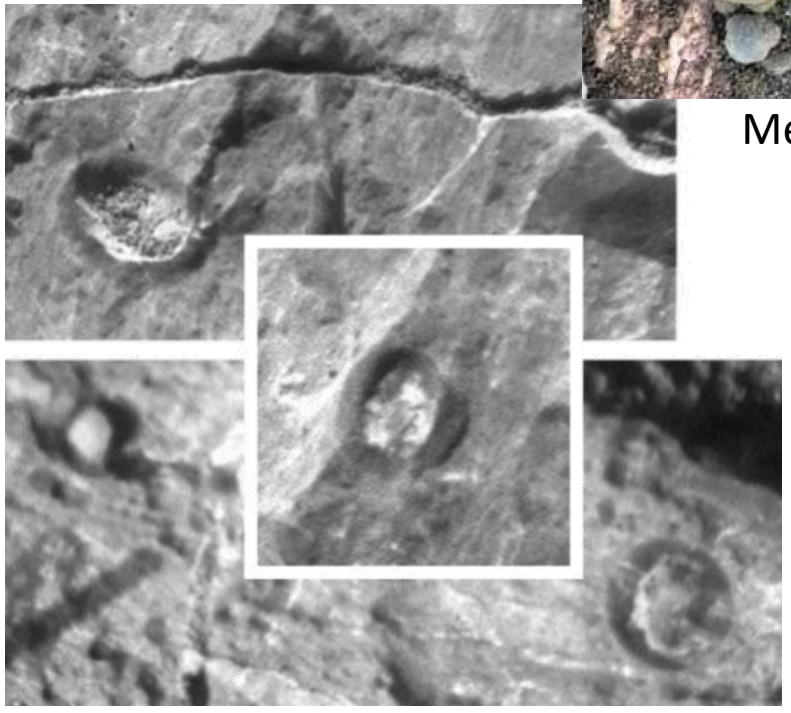
Concretions on Mars

Concretions defined here as hard, relief-enhanced features formed from authigenic precipitation of a mineral cement during diagenesis.

Yellowknife Bay solid, hollow, filled nodules
[Stack et al., 2014 JGR]



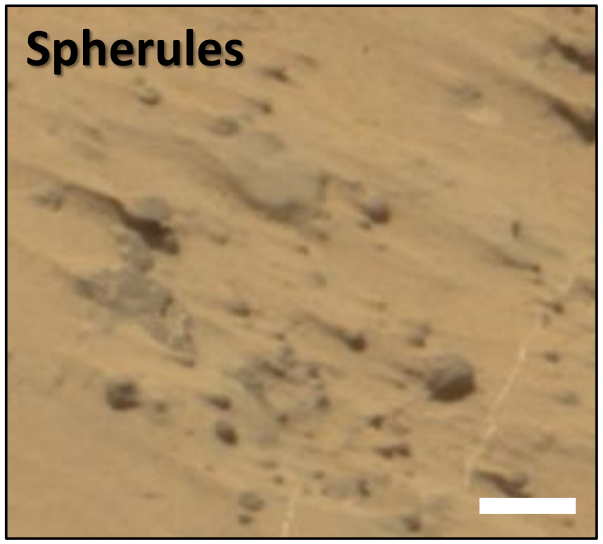
Meridiani Planum “blueberries”
[Calvin et al., 2008 JGR]

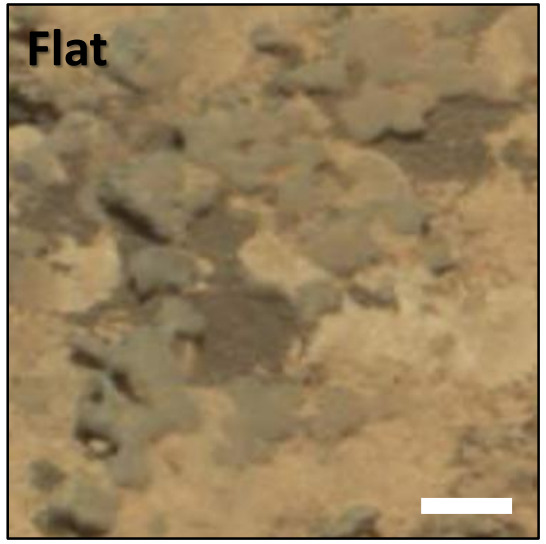


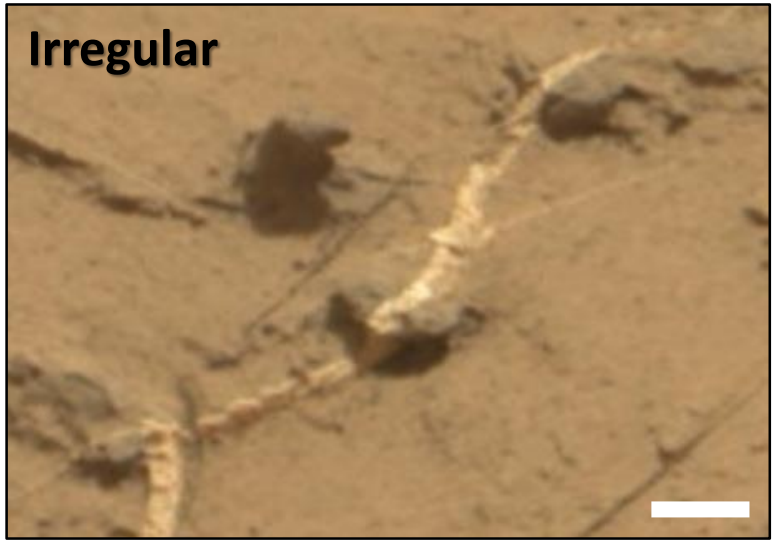
Meridiani hollow spherules
[Fairen et al., 2014 LPSC]

Concretion Morphologies in the Murray Fm.

Discrete concretionary bodies: Indicate an increased cement-to-sediment ratio.

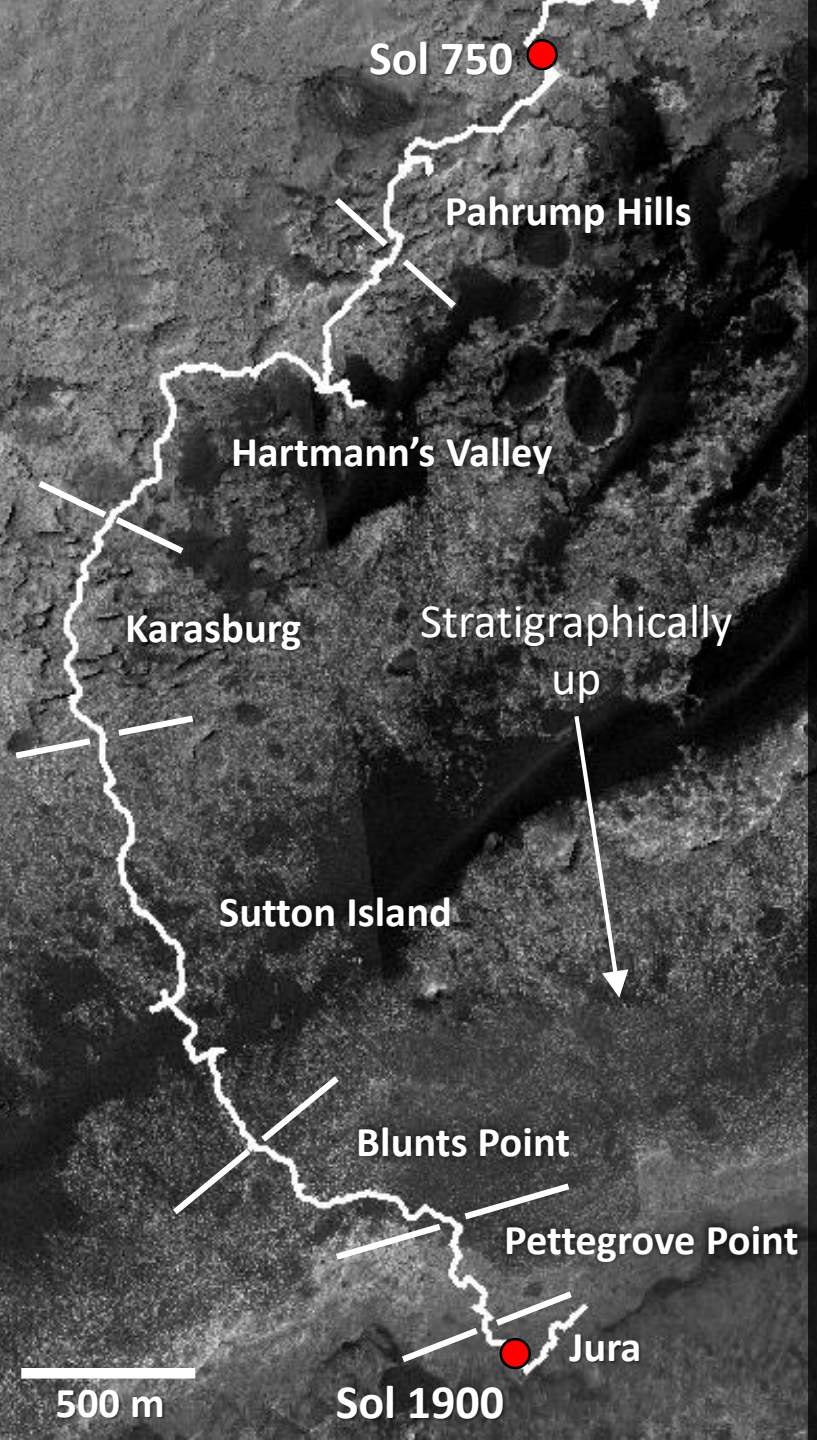






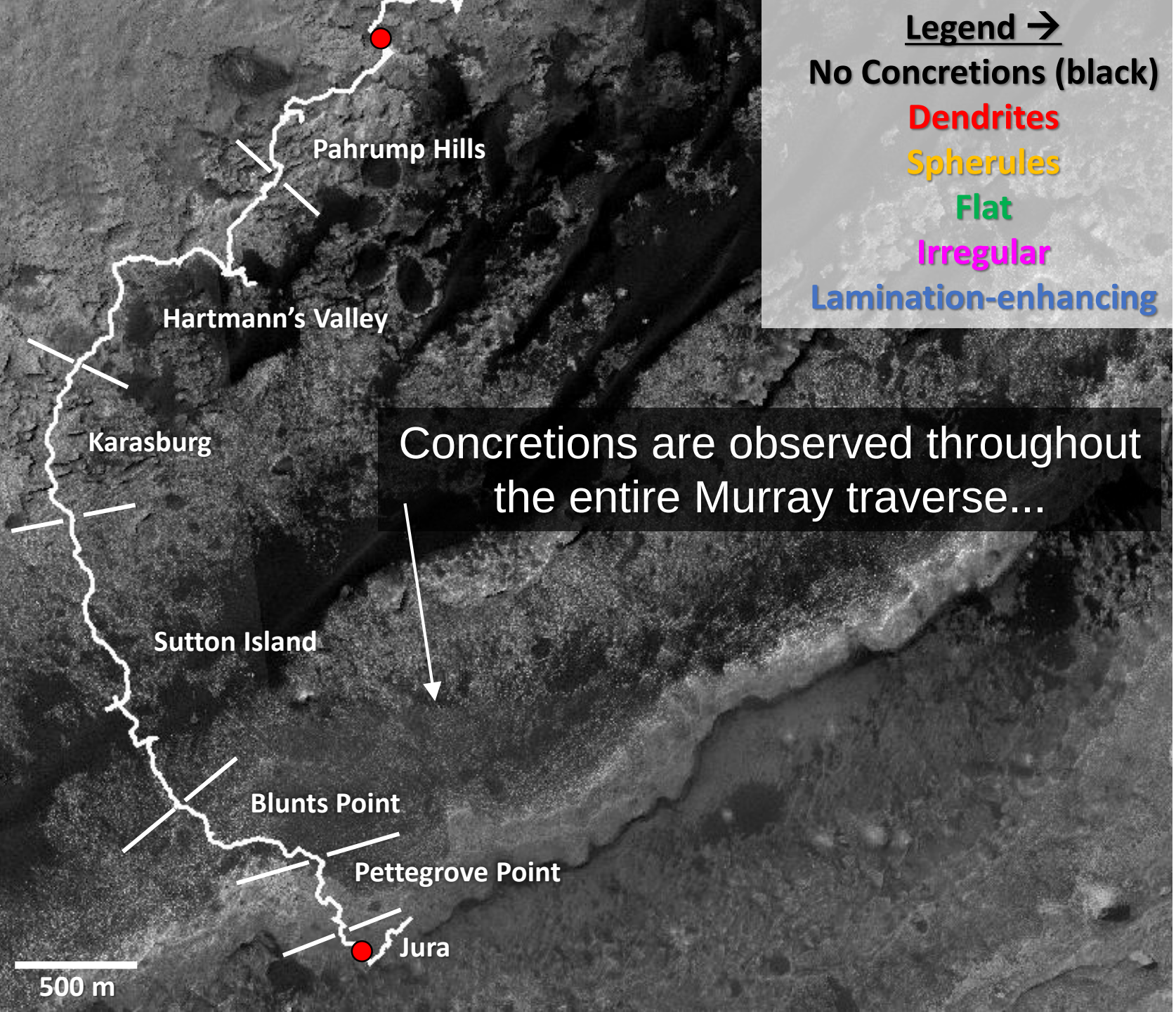
Lamination-enhancing features: Indicate a lower cement-to-sediment ratio.

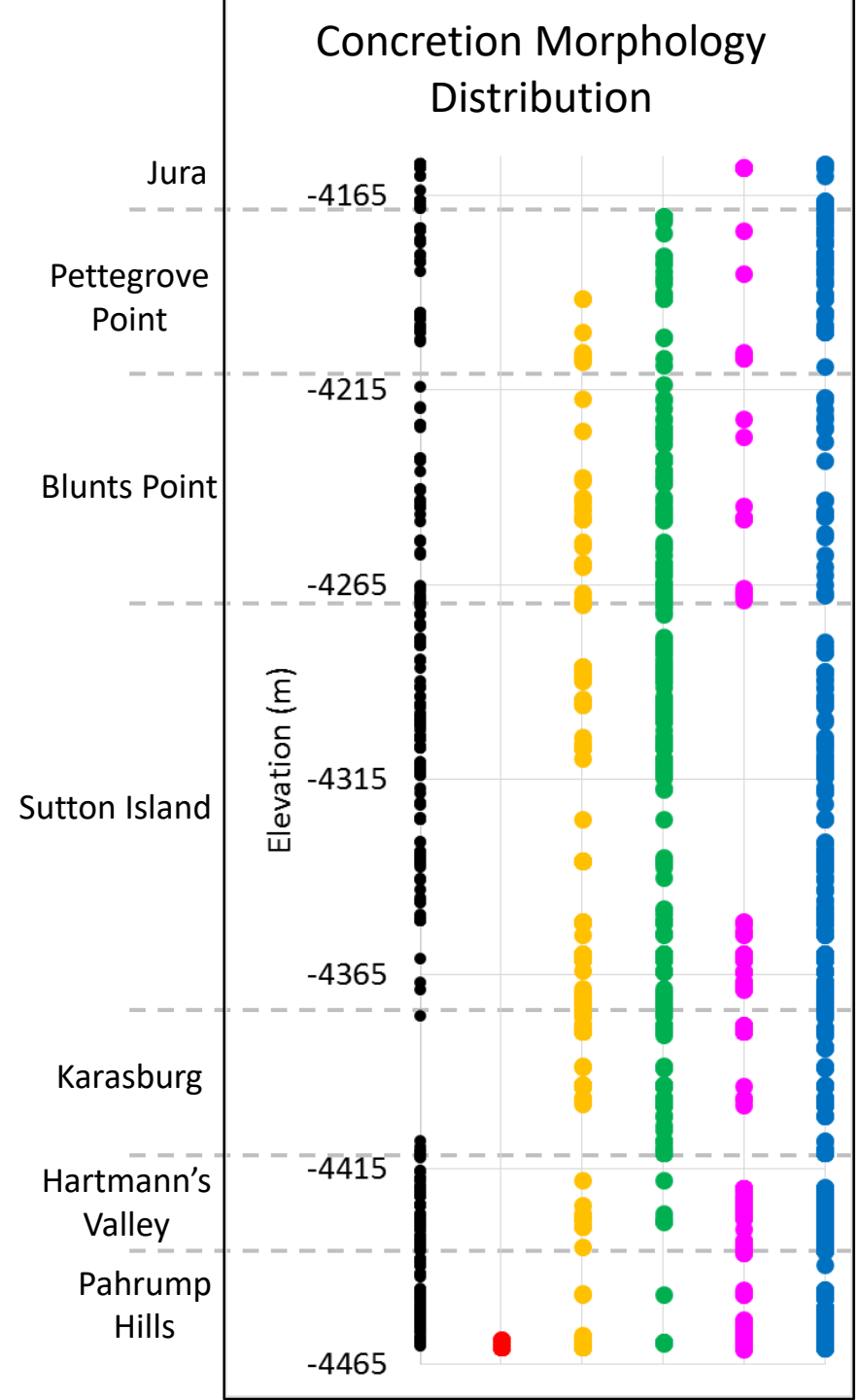
Mastcam images: mcam3304; 7124; 8800; 7190; 4904; 3423



Motivating Questions

- What is the stratigraphic distribution of concretion morphology and size in the Murray?
  - Assessed from Mastcam and MAHLI images from Sols 750-1900.
- Are these concretions early or late diagenetic products?
  - How do the concretions relate to host rock laminations?
- How many diagenetic episodes occurred in the Murray and when did they occur? What were the fluid chemistries?
  - What is the relation of concretions to veins?
  - What is the chemistry of the concretions?

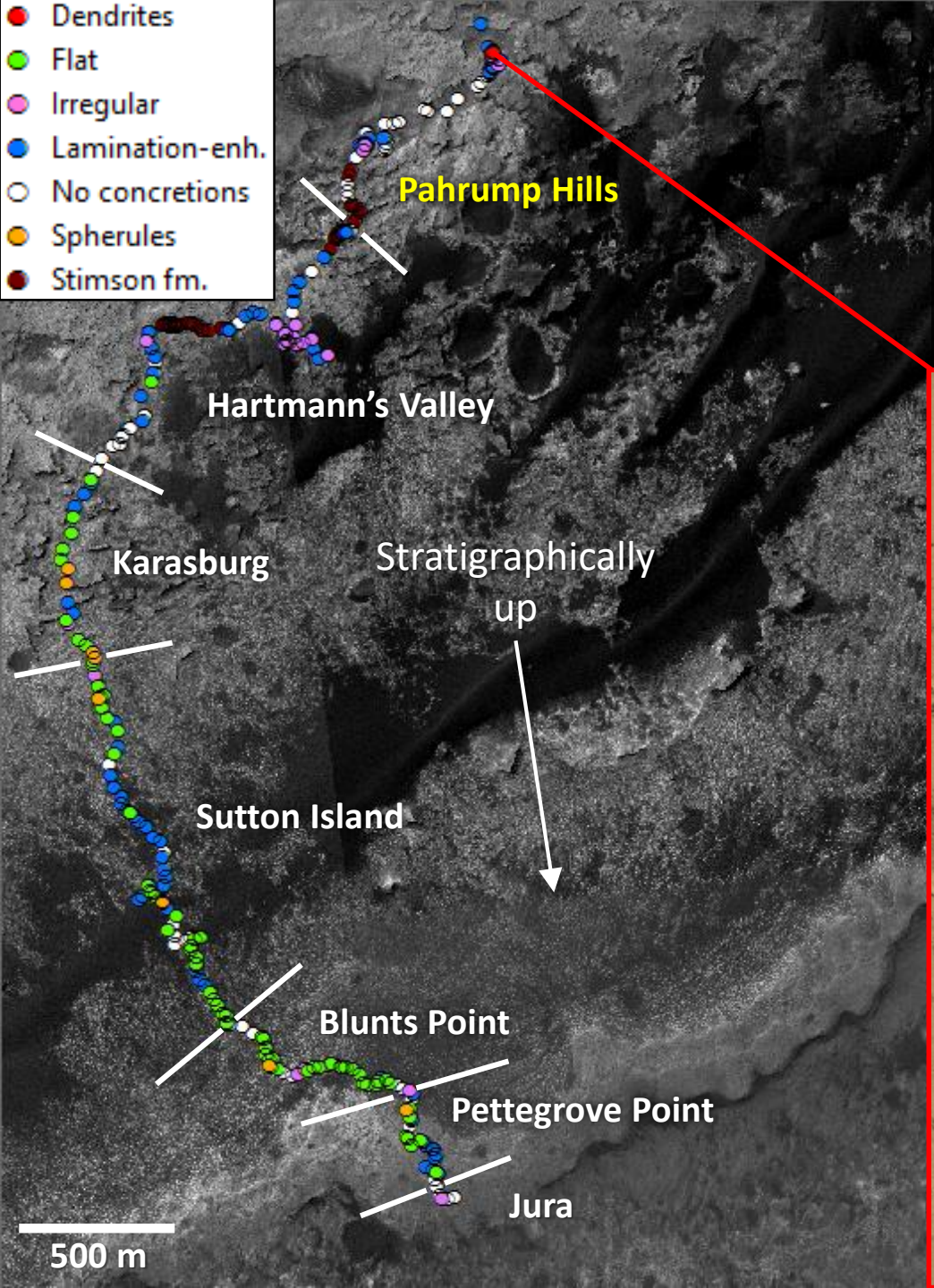

Legend →
No Concretions (black)
Dendrites
Spherules
Flat
Irregular
Lamination-enhancing
Concretions are observed throughout the entire Murray traverse...
Pahrump Hills
Hartmann's Valley
Karasburg
Sutton Island
Blunts Point
Pettegrove Point
Jura
500 m


Concretion Morphology Distribution
Jura
Pettegrove Point
Blunts Point
Sutton Island
Karasburg
Hartmann's Valley
Pahrump Hills
-4165
-4215
-4265
-4315
-4365
-4415
-4465
Elevation (m)


Dendrites
Flat
Irregular
Lamination-enh.
No concretions
Spherules
Stimson fm.
... But there are stratigraphic trends in dominant concretion morphology, or concretion “facies”.
Pahrump Hills
Hartmann’s Valley
Karasburg
Stratigraphically up
Sutton Island
Blunts Point
Pettegrove Point
Jura
500 m

Stratigraphic Trends

Dendrites are found only at the base of the **Pahrump Hills** member and are Mg-enriched [Kah, 2015 LPSC; Nachon, 2017 Icarus; Minitti, #1560 this morning].



Stratigraphic Trends

Irregular concretions and **lamination-enhancing features** are more prevalent in **Pahrump Hills and Hartmann's Valley**.

- Dendrites
- Flat
- Irregular
- Lamination-enh.
- No concretions
- Spherules
- Stimson fm.

Pahrump Hills

Hartmann's Valley

Karasburg

Stratigraphically up

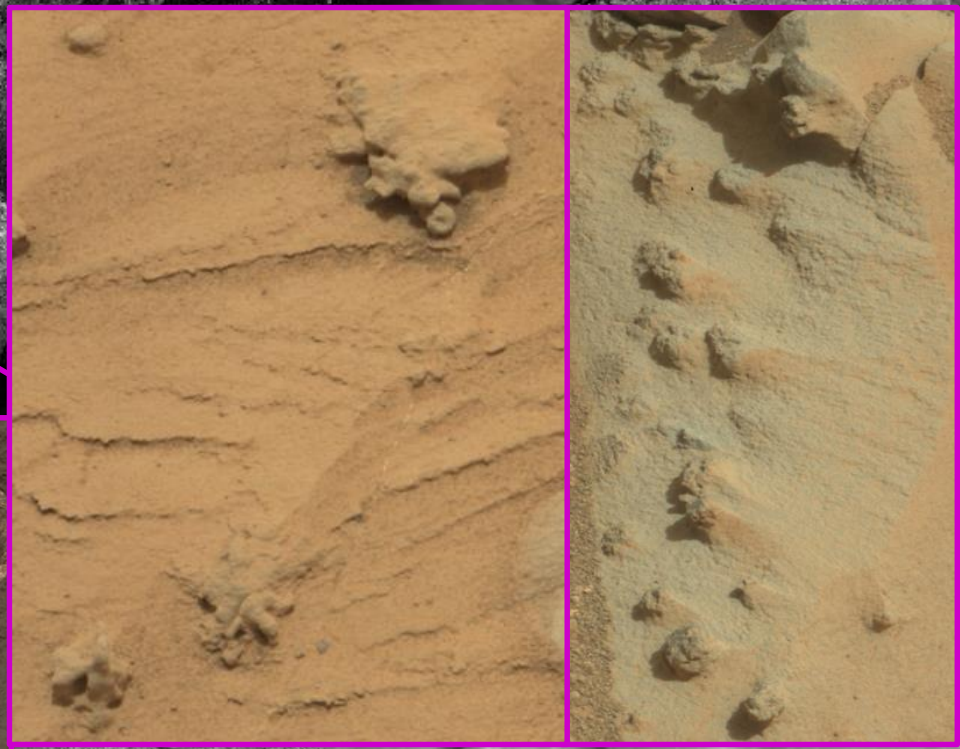
Sutton Island

Blunts Point

Pettegrove Point

Jura

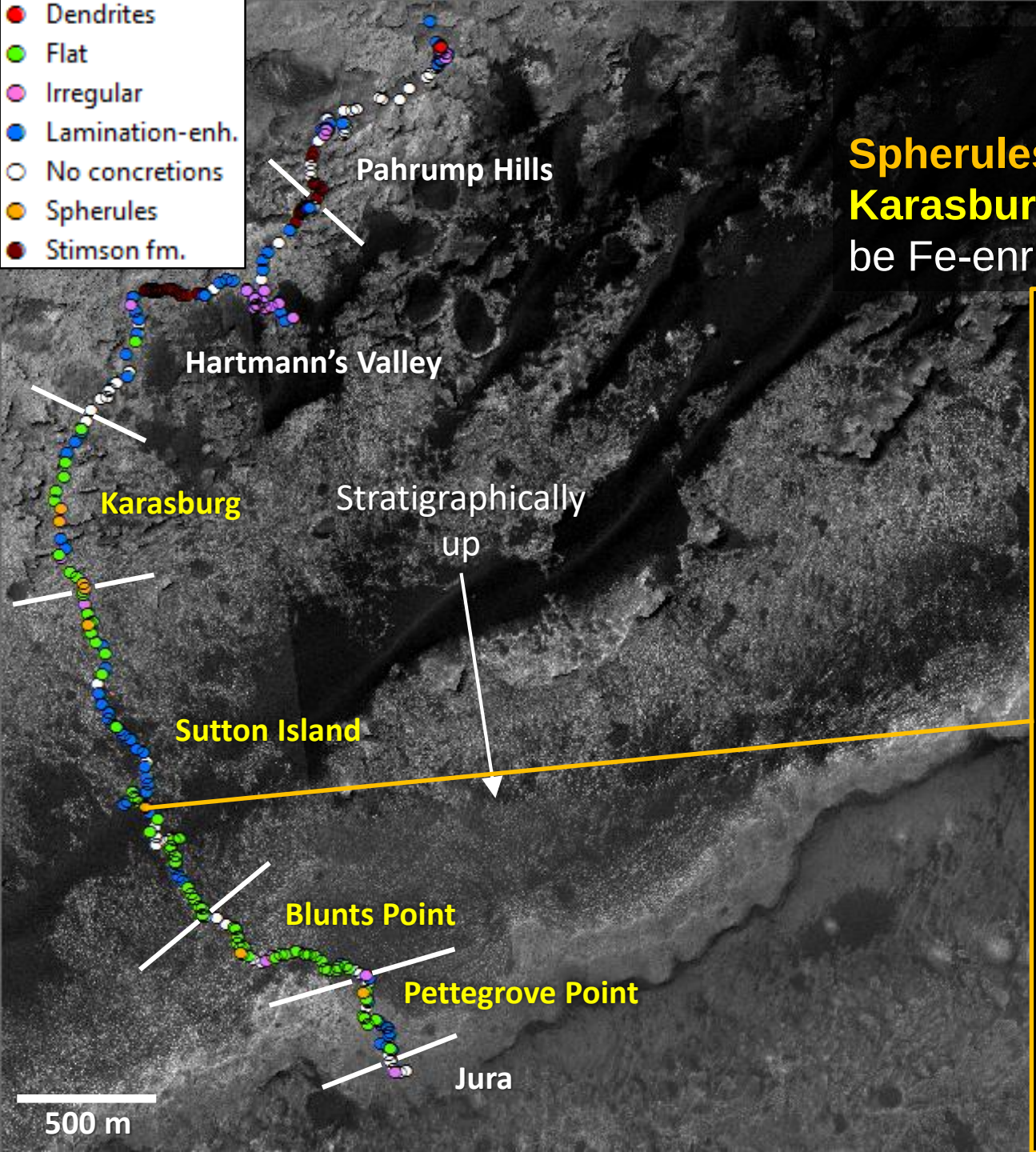
500 m

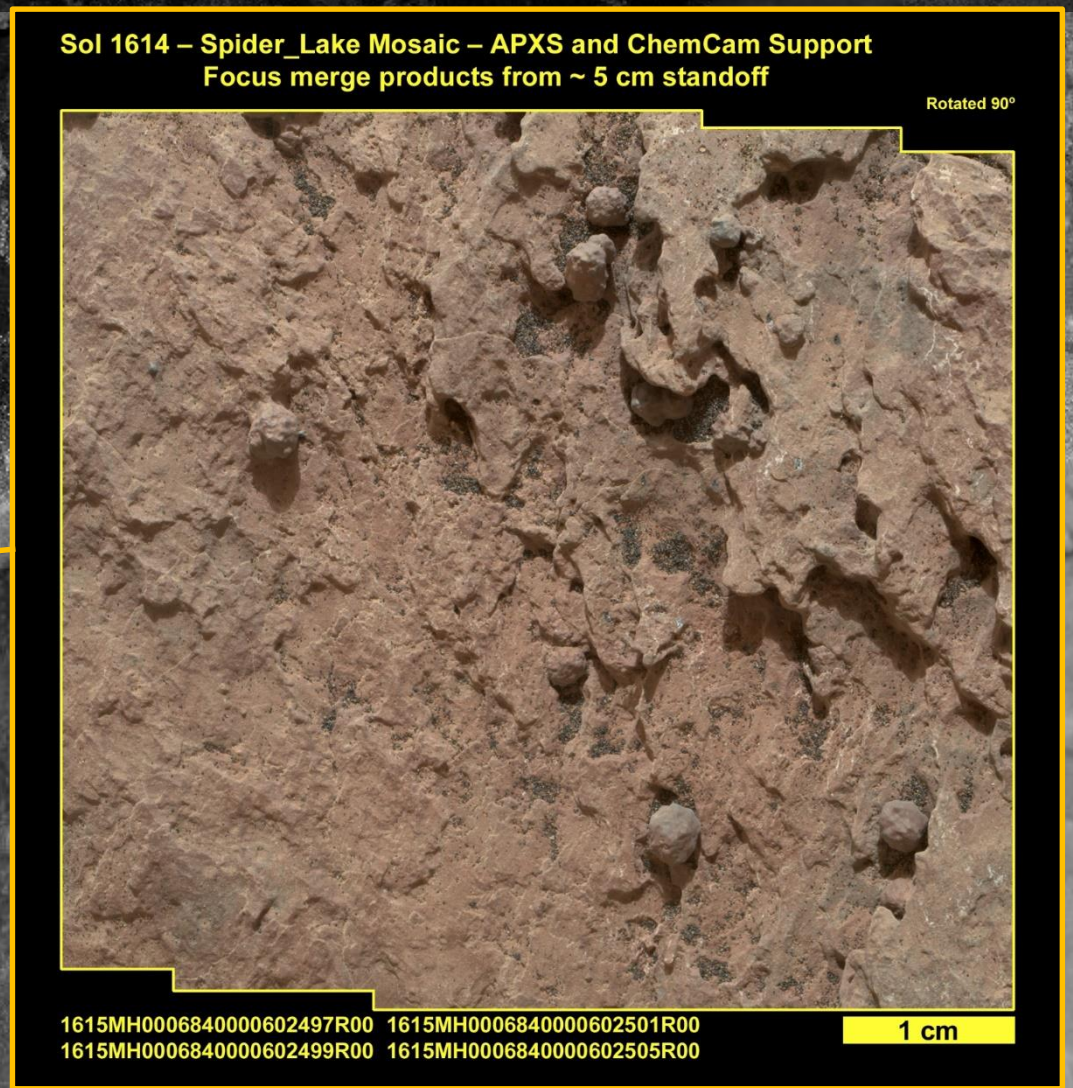


Sols 807, 871, 1250 / mcam03538, 3815, 5834

Stratigraphic Trends

Spherules and **flat** concretions are prevalent in the **Karasburg to Pettegrove Point** members. **Spherules** tend to be Fe-enriched (up to 30% FeOt) compared to the host rock.



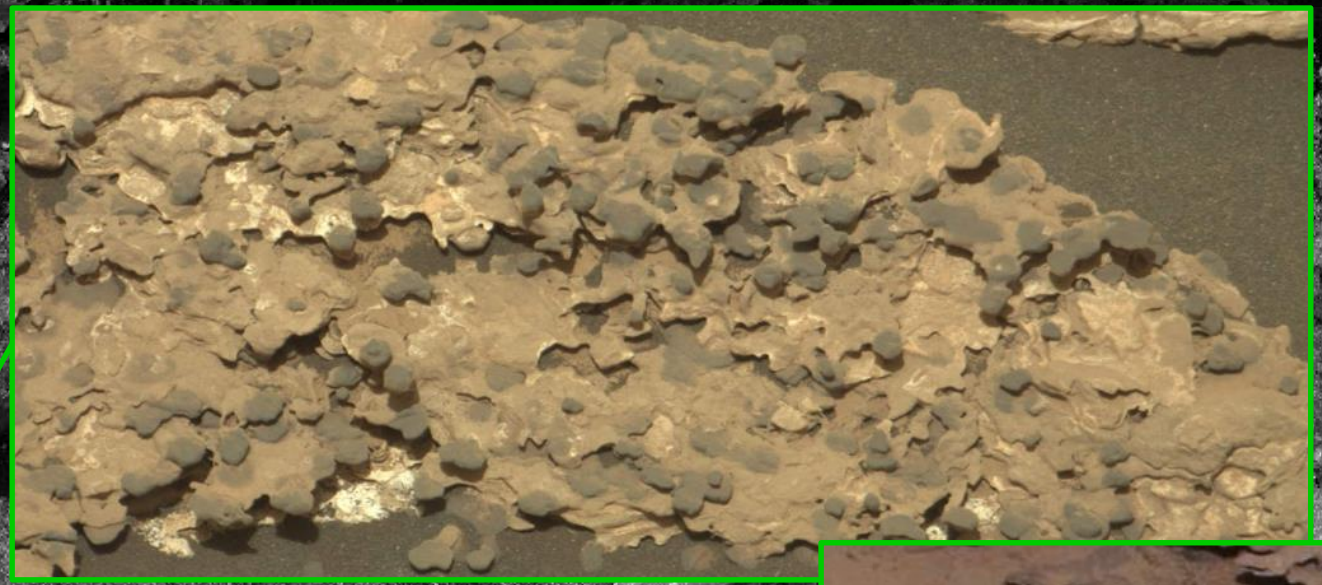


Stratigraphic Trends

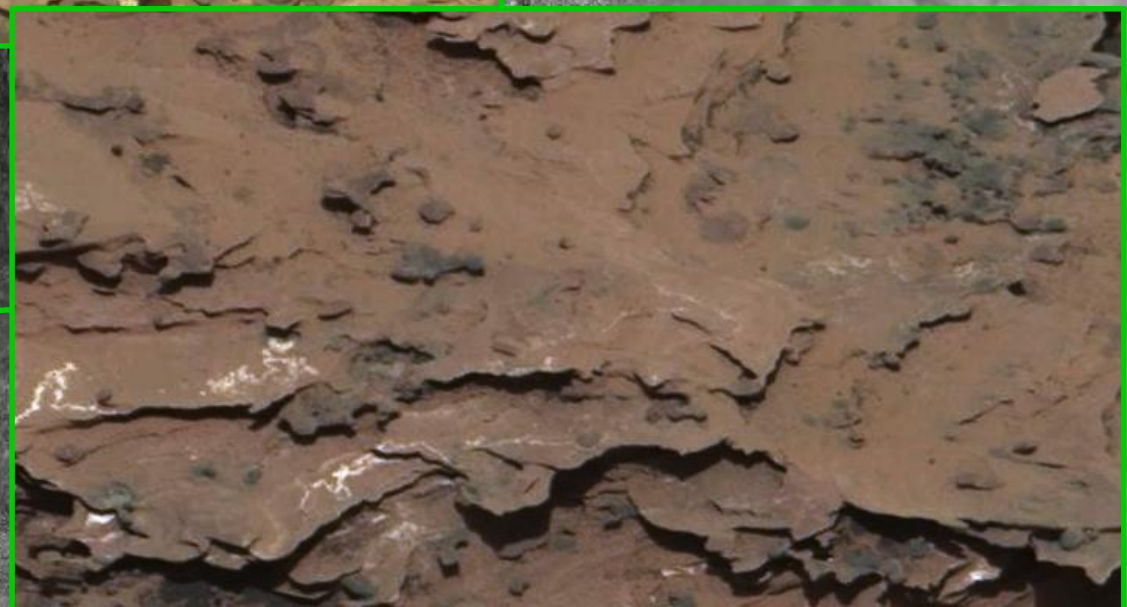
Flat concretions also show a diversity of morphologies and are variably enriched in Mg, Fe, Mn, P [Meslin, #1447 previous talk; Lamm, #2903; Rapin, #2936 next talk].

Dendrites
Flat
Irregular
Lamination-enh.
No concretions
Spherules
Stimson fm.

Pahrump Hills
Hartmann's Valley
Karasburg
Sutton Island
Blunts Point
Pettegrove Point
Jura
500 m



Sols 1718, 1753 / mcam08973, 9164



Stratigraphic Trends

Lamination-enhancing features are present throughout the **entire Murray** formation and suggest diagenetic cementation even if discrete concretionary bodies were not formed.

- Dendrites
- Flat
- Irregular
- Lamination-enh.
- No concretions
- Spherules
- Stimson fm.

Pahrump Hills

Hartmann's Valley

Karasburg

Stratigraphically up

Sutton Island

Blunts Point

Pettegrove Point

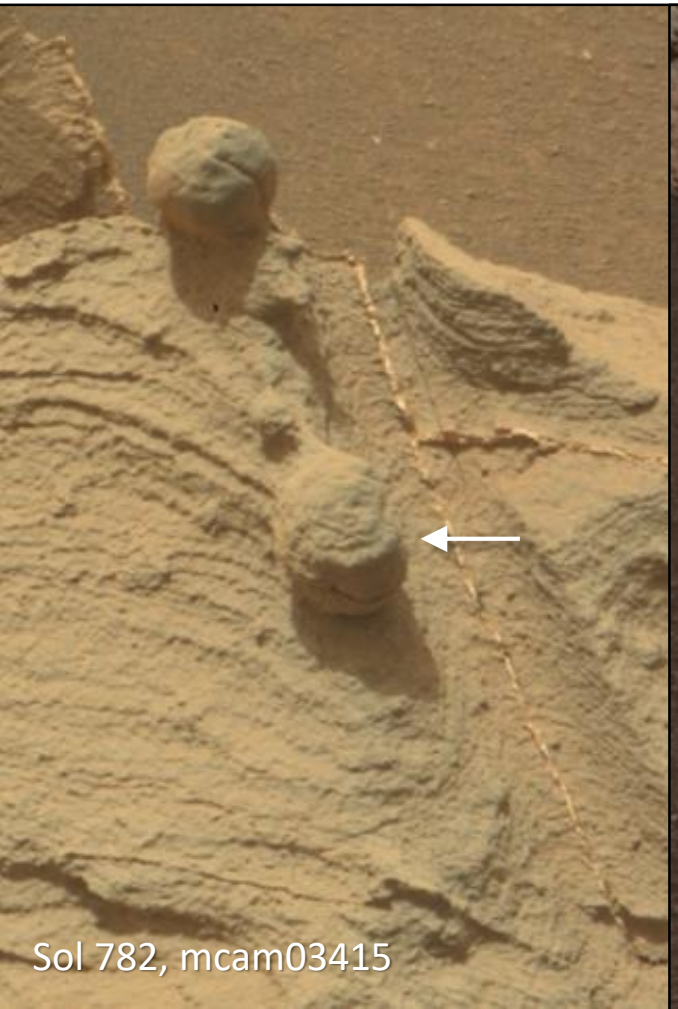
Jura

500 m

Sols 785, 1516 / mcam03423, 7723

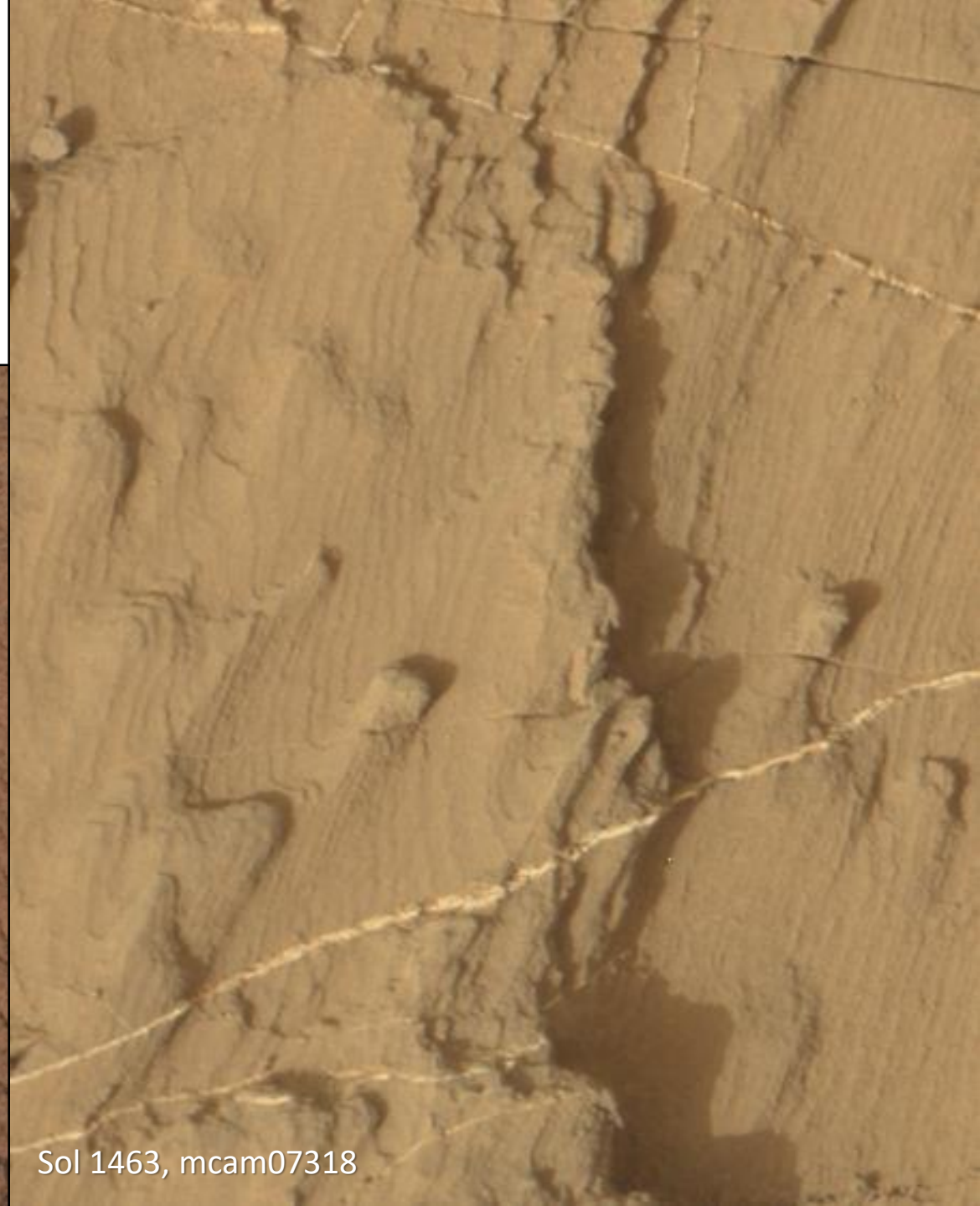
Evidence for Late-Stage Diagenesis

Some concretions preserve host rock laminations within the concretion body.



Sol 782, mcam03415

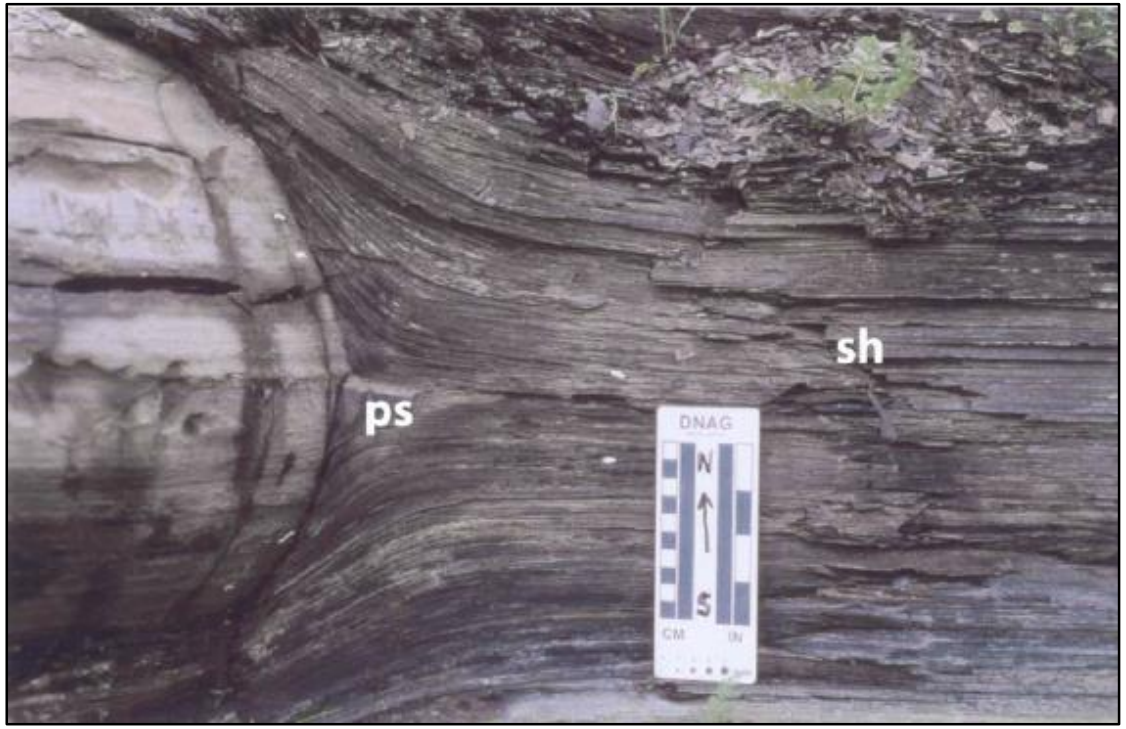
Sol 792, mcam03447



Sol 1463, mcam07318

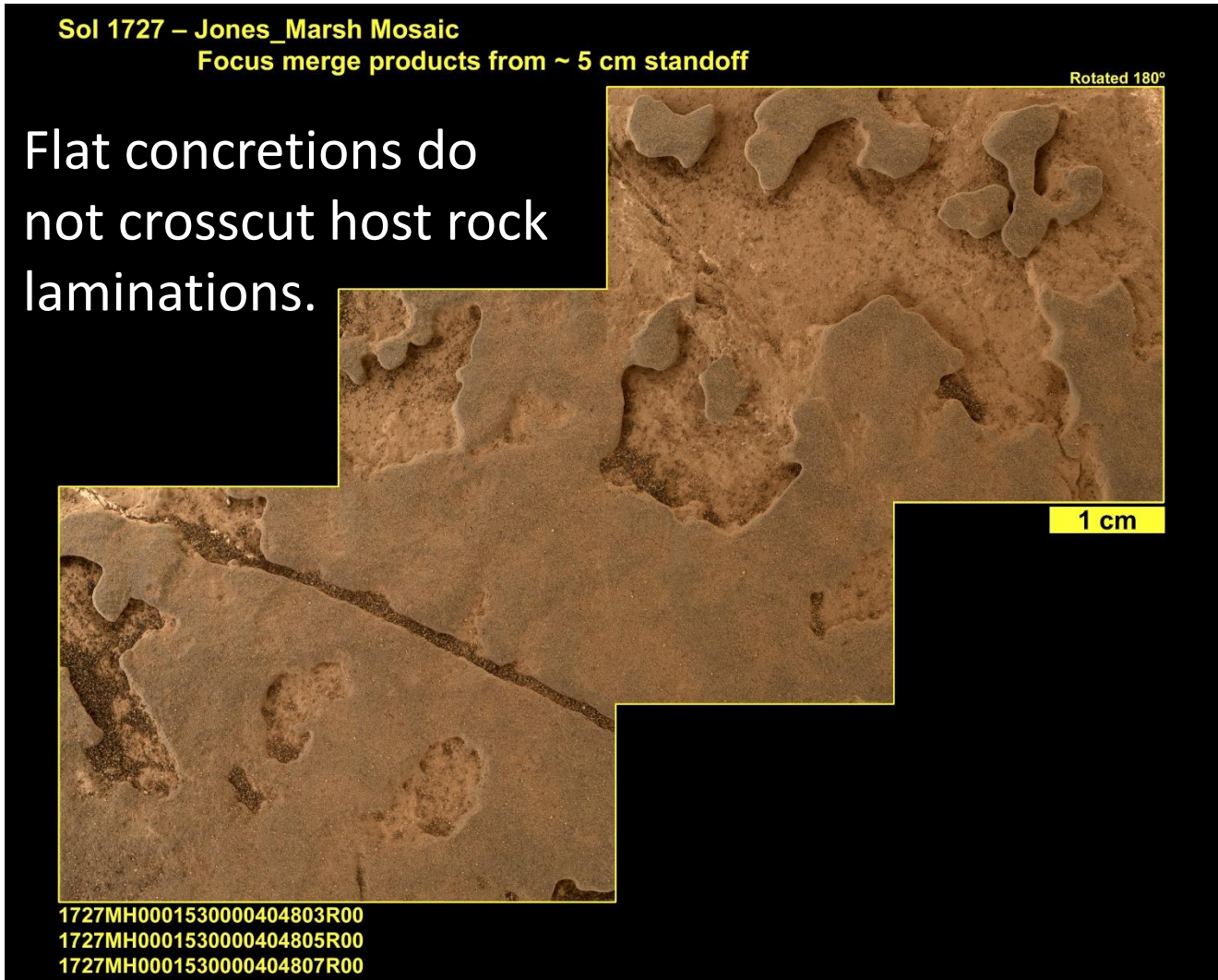
Evidence for Late-Stage Diagenesis

No concretions deflect host rock lamination, implying concretion formation after the compaction and lithification of sediments.



Lash and Blood, 2004 Chemical Geology

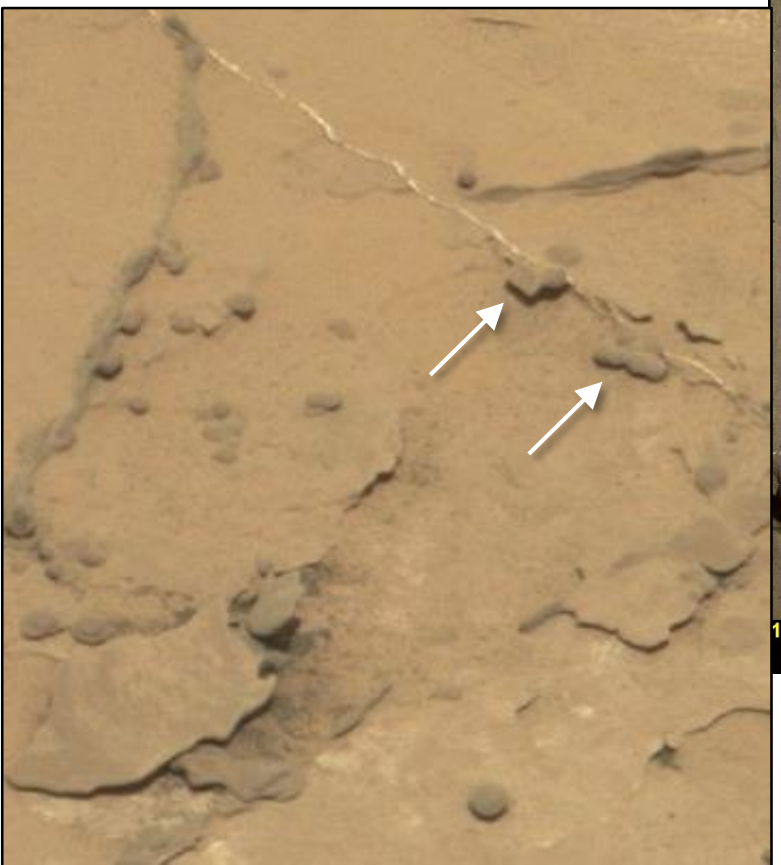
Flat concretions are an exception and may represent depositional or early diagenetic conditions.

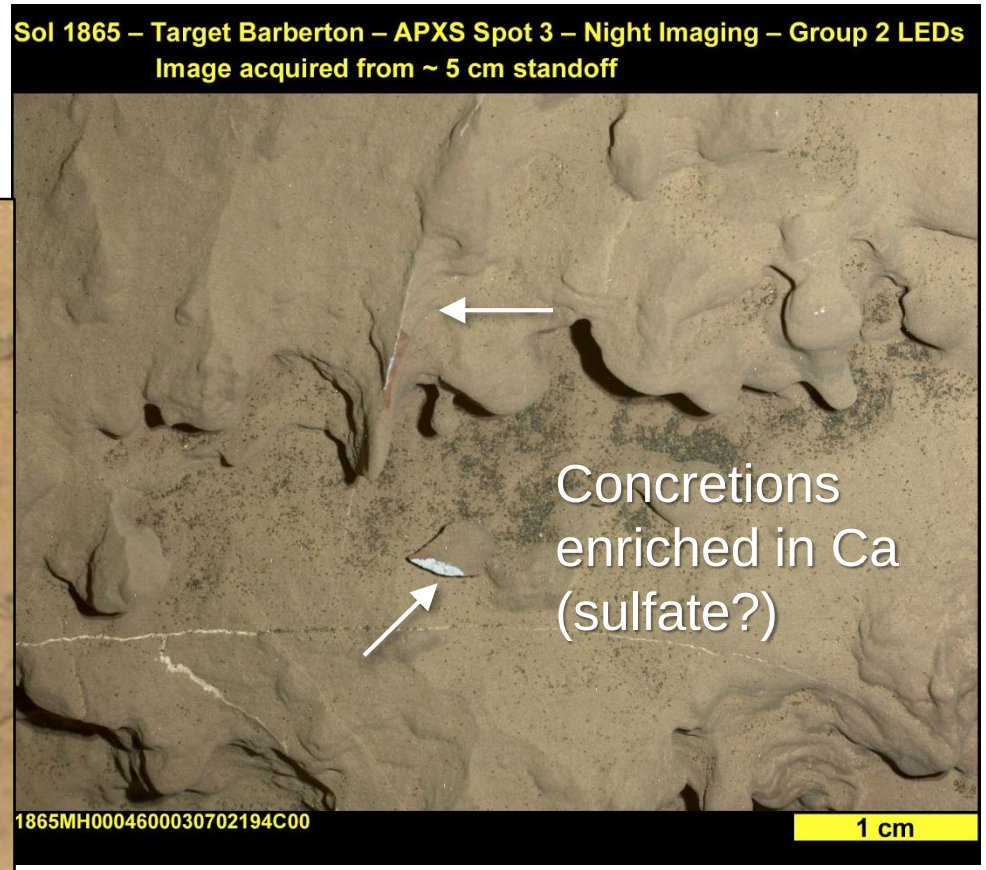


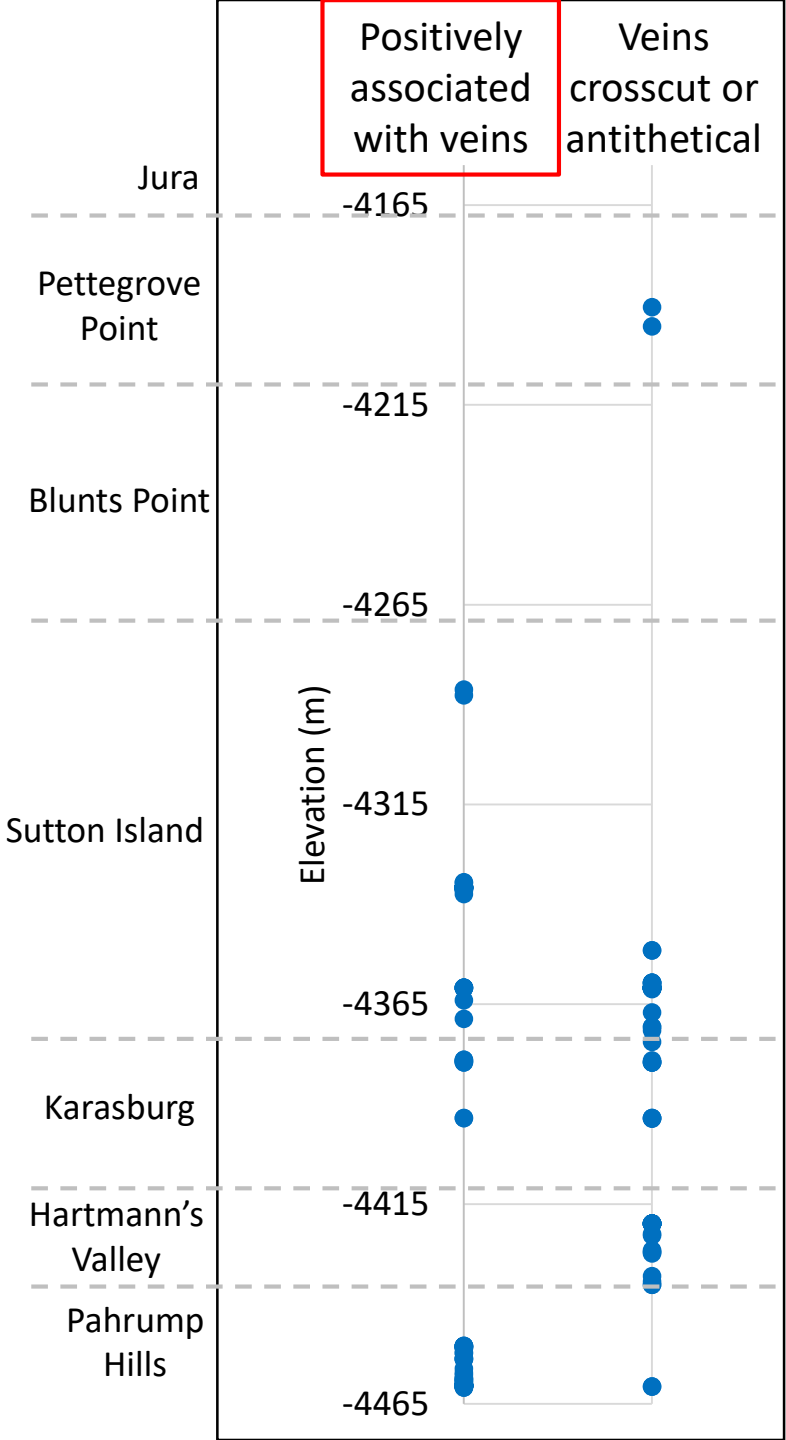
Evidence for Multiple Diagenetic Episodes

Concretions are sometimes positively correlated with veins and may have formed concurrently.

Sol 1752, mcam09160



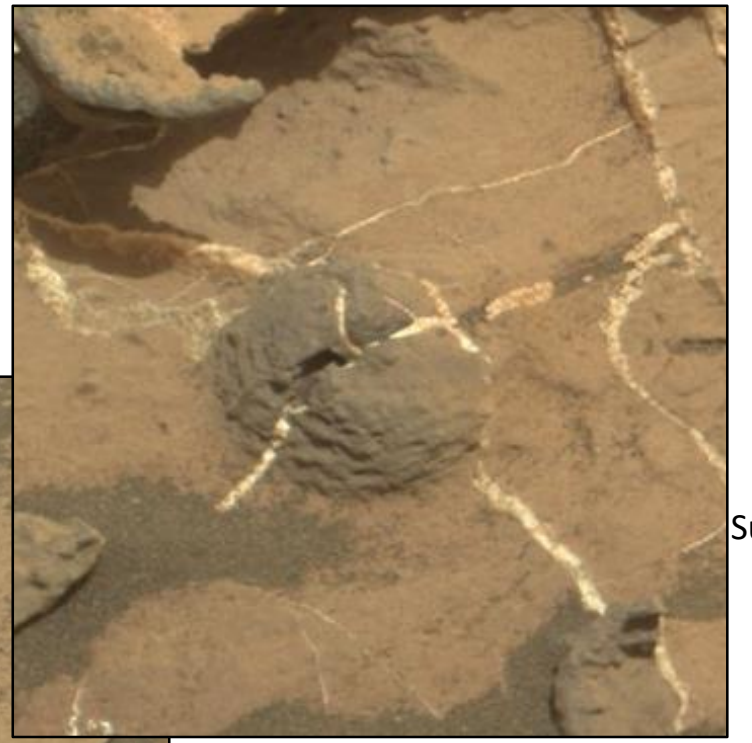




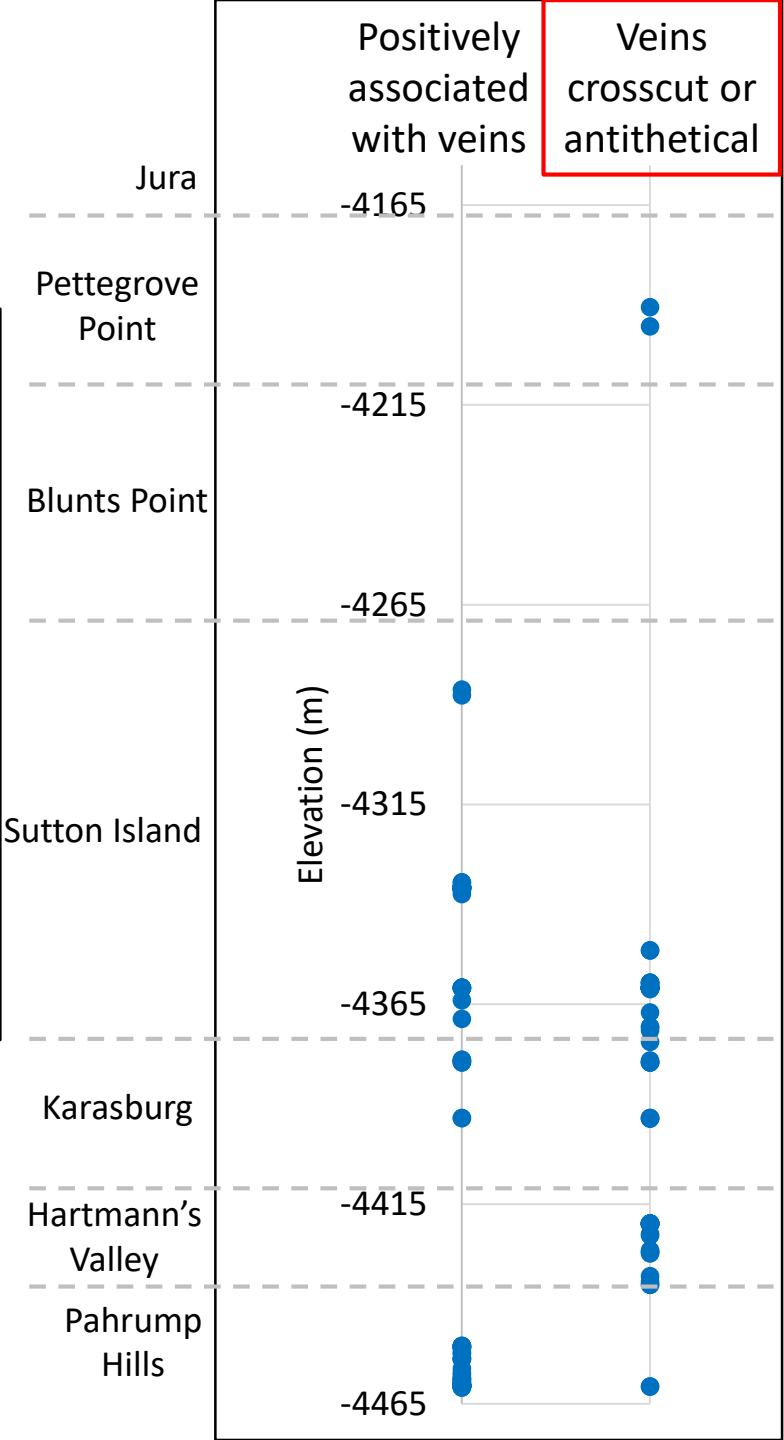
Evidence for Multiple Diagenetic Episodes

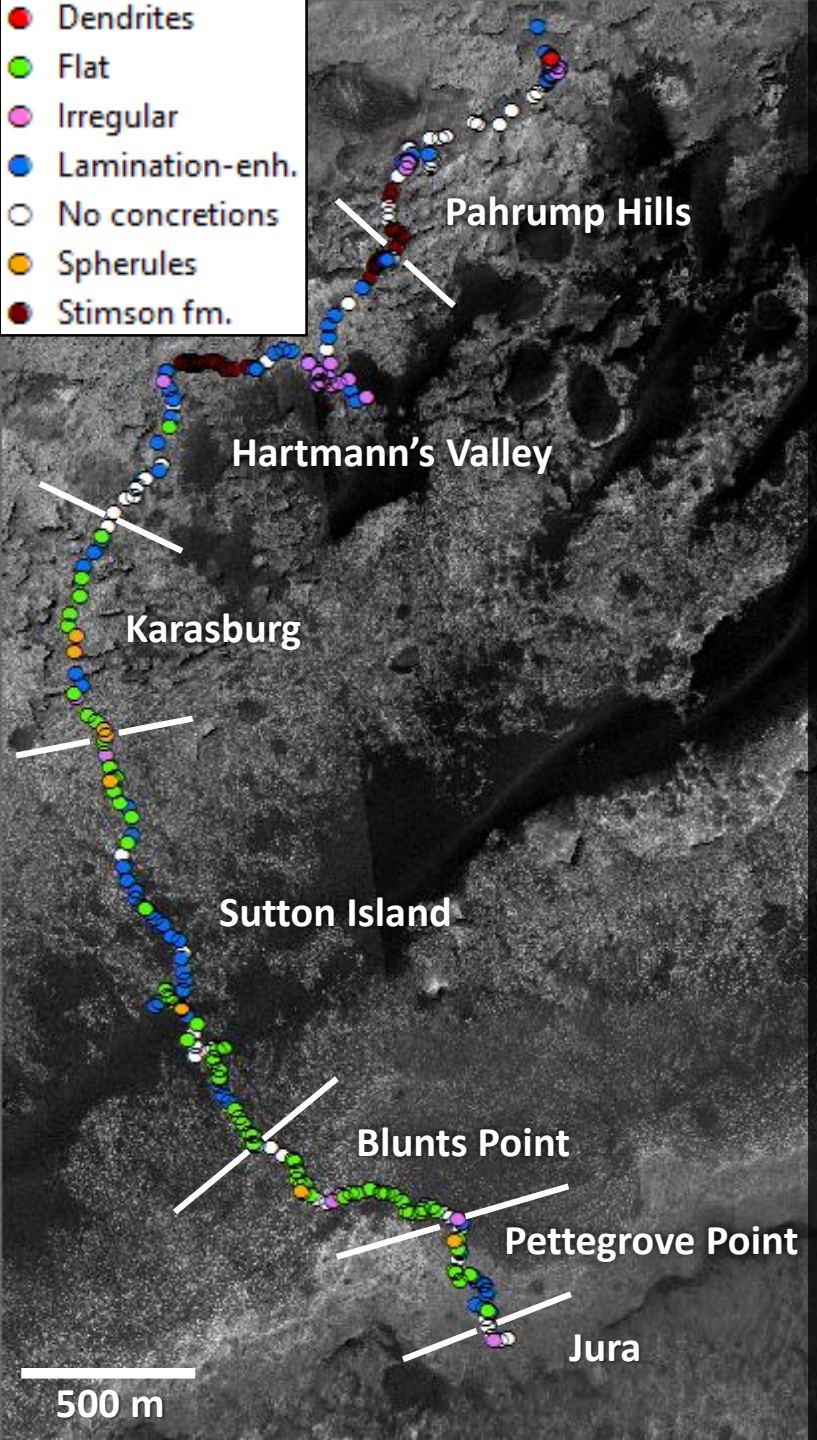
Concretions can also be crosscut by or are antithetical with veins, suggesting later vein formation.

Sol 1828, mcam09454



Sol 1441, mcam07126

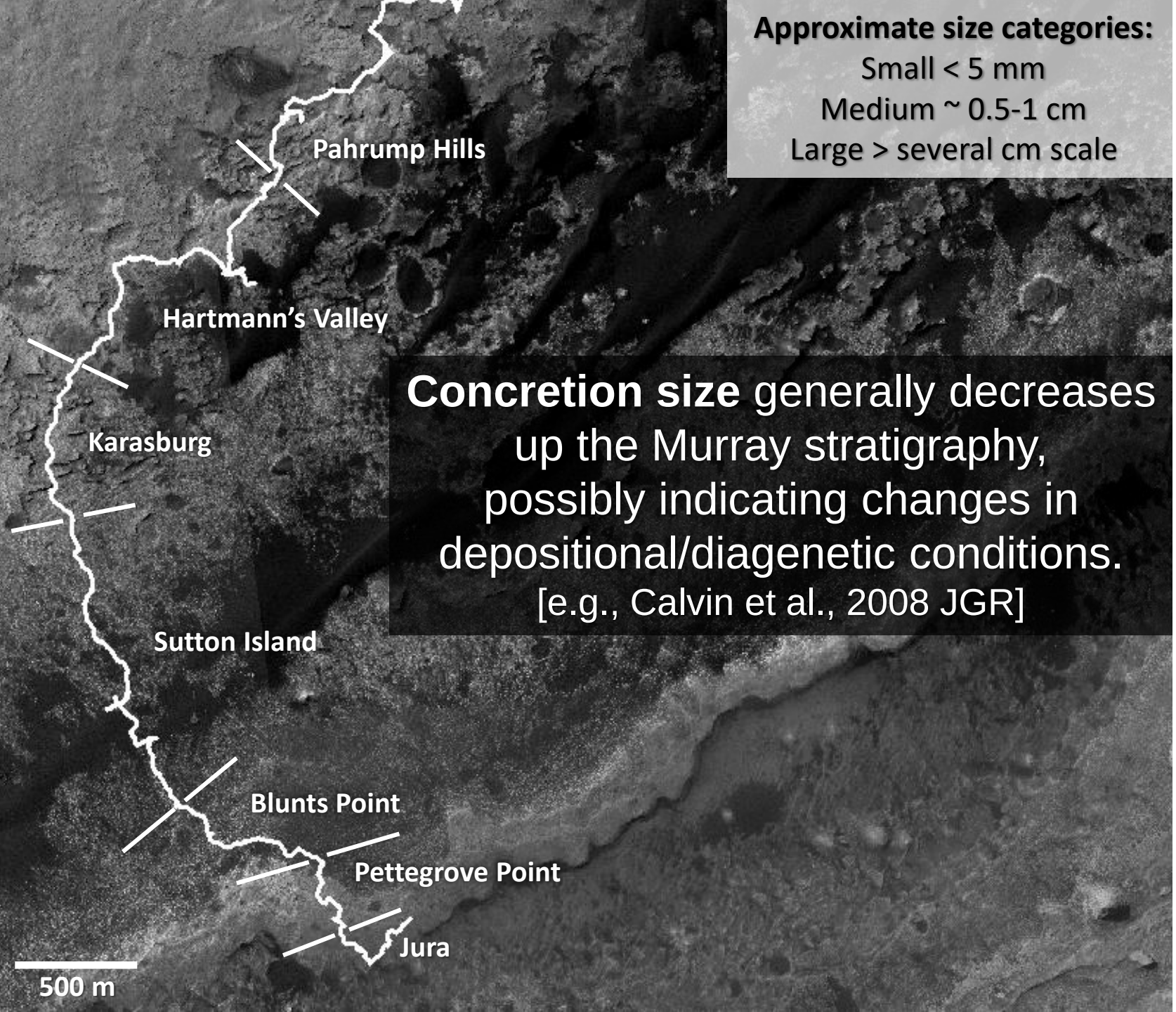


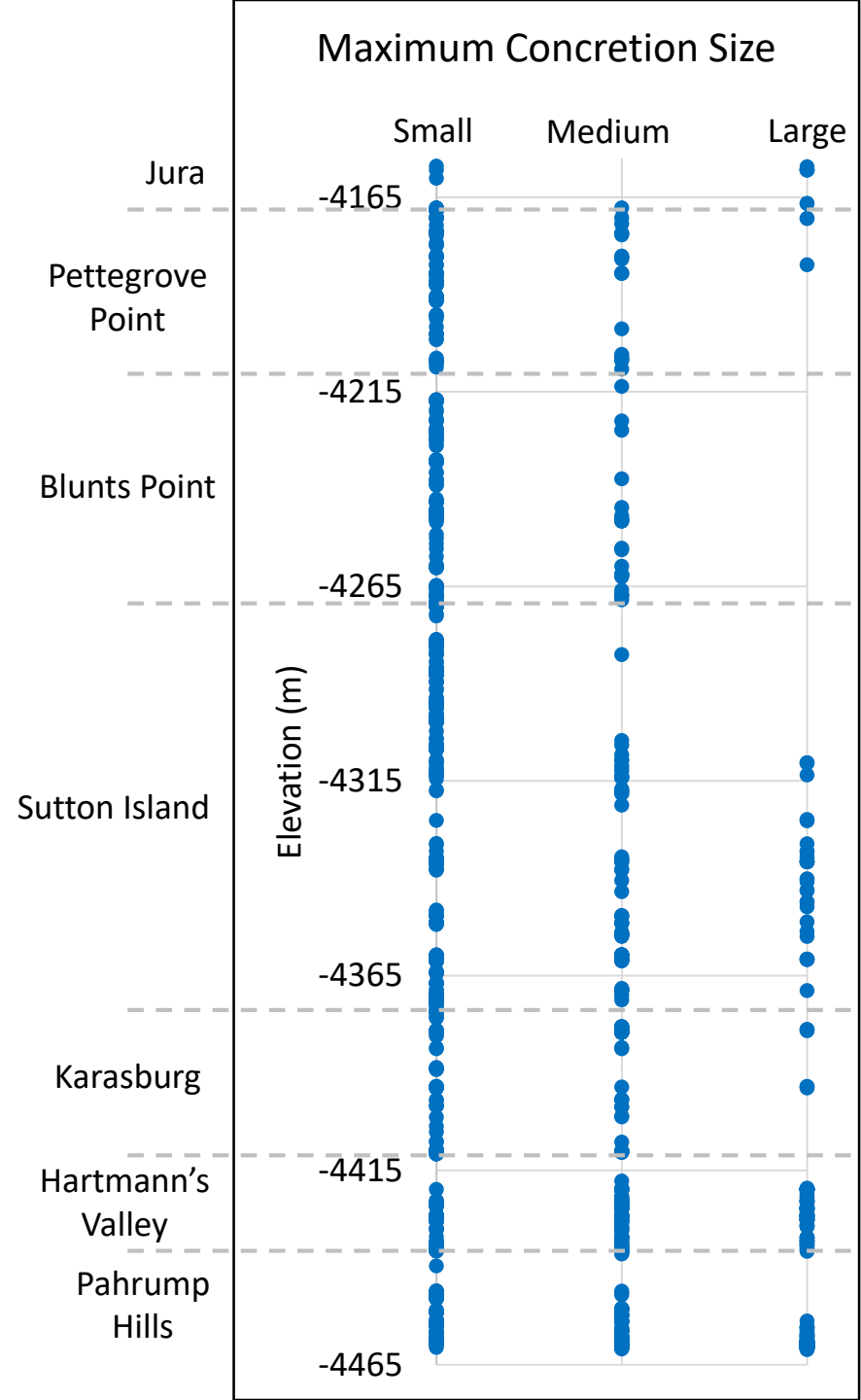


Summary

- Concretions are prevalent and morphologically diverse in the Murray fm. Certain morphologies are dominant in some members.
- **Most concretions are likely late diagenetic products** as they do not deflect host rock laminations; flat concretions are an exception and may be early diagenetic products.
- Evidence supporting multiple diagenetic episodes:
  - Veins can postdate or predate/form contemporaneously with concretions. Consistent with hypothesis of multiple episodes of vein formation [*e.g., Garden City, Nachon, 2017 Icarus; Kronyak, 2015 AGU]* and alteration halos *[Yen, #2690 Tues morning]*.
  - Different concretion compositions suggest distinct fluid compositions.
  - Multiple concretion types in the same workspace may require multiple diagenetic episodes to form.

Backup


Approximate size categories:
Small < 5 mm
Medium ~ 0.5-1 cm
Large > several cm scale
Pahrump Hills
Hartmann's Valley
Karasburg
Sutton Island
Blunts Point
Pettegrove Point
Jura
500 m
Concretion size generally decreases up the Murray stratigraphy, possibly indicating changes in depositional/diagenetic conditions.
[e.g., Calvin et al., 2008 JGR]


Maximum Concretion Size
Small
Medium
Large
Jura
Pettegrove Point
Blunts Point
Sutton Island
Karasburg
Hartmann's Valley
Pahrump Hills
-4165
-4215
-4265
-4315
-4365
-4415
-4465
Elevation (m)